Improving the accuracy on the efficiency measurements in the acceptance tests of hydraulic machines: a nice lesson for manufacturers, utilities, engineers and independent testers.

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Abstract.

Recently the San Esteban II extension in the river Sil (northern of Spain) has been put into operation. The new machine (rated point: H=95 m; Q=200 m^3/s; P= 176 MW) has been set into a cavern. A number of geological problems have let us to put the cavern upstream than initially planned. The penstock piping is very complex leading to difficulties in discharge measurement. In the other hand, a best accuracy has been found in order to assure the fulfilment of warranted performances. In this sense it's well known the key role played by the discharge measurement. A number of solutions have been studied both in the civil and costs aspects and the best accuracy reached. The choice has been focused in an ultrasonic flow-meter of 18 paths in two crossed plans.

A traditional problem to state the accuracy in the discharge measurement is the excessively large values proposed by the current version of the IEC60.041 standard (in the opinion of the authors). It could be remembered to the participants the fact that the date of publication was 1991, but the date of the redaction of the annex J of this standard (ultrasonic measurements) is as old as 1981! Since a number of improvements in the comprehension of the fluid flow motions, etc. has occurred. The great effort of researchers (a number of PhD Thesis), the new generation flow meter of 18paths, etc., are arguments enough to revise these figures of accuracy.

Last but not least, the loss of revenues for a fall in the actual efficiency of the machine had to be avoided. A severe penalty was introduced for each 0,1% in less efficiency than specified in the contract. Since the penalties, loss in efficiency and accuracy of the tests are intimately connected, a special attention has been devoted to this last factor. Then for the San Esteban II has been fixed contractually a scope in tolerance of ±0,5% in discharge and in ±0,585% in efficiency; the final values would be determined after the tests regarding d the hydraulic conditions or other non-favourable aspects.

The tests have been conducted over two heads with excellent results: the accuracy in discharge has been of only ±0,398% (±0,676% for the efficiency). All the figures of efficiency have fallen into the tolerance band of the contractual values. Results are very close to the planned values and the hill chart.

A number of valuable conclusions for everybody (manufacturers, utilities, etc.) have been deduced and discharge data will be presented.

1.- San Esteban scheme and extension

San Esteban Power Station is located in the river Sil, main tributary of river Miño, near the city of Orense (Galicia, in the north-west of Spain). The Plant, placed in a very spectacular landscape (the “Sil Canyon”), was put into operation in 1956, with four sets making a total of 240 MW with a discharge of 300 m^3/s. In fact, was at his time the most power-full in Spain. See photo no.1. The scheme stores 213,20 hm^3. The annual ratio of energy production is 940 GWh.

The relatively great river basin (7.143,4 km^2) and frequent rains (with a total volume per year of 5.238 hm^3) have got a number of floods: it was very common to open the spillway gates every year during the rain season.

In order to minimize the diversions spillways, relatively common, and to increase the peak energy ratio of the scheme, an extension has been study many years ago and afforded between the autumn 2008 through the Christmas 2012. In this way ssignificant reductions in the diversions have been achieved: a 40% of the total; the increasing in production is 110 GWh/year. The new Francis set has been designed with the following characteristics:

Rated head.	95 m
Rated discharge:	200 m^3/s,
Rated power:	176 MW (at the generator terminals)

The new power station is disposed underground. The predominant type of rock in San Esteban is the granite. However a significant number of abnormalities (such as diabases) had us to move the cavern upstream. This decision means a longer than normal outlet discharge and to short the pressure side loop. See figures no.1 and 2. A shorter loop upstream means fewer chances to have long lengths to get as “standard conditions” in flow measurements. The San Esteban II penstock has been constructed in concrete until the lower bend and in steel from here to the spiral case inlet; diameter is 7,5 m.

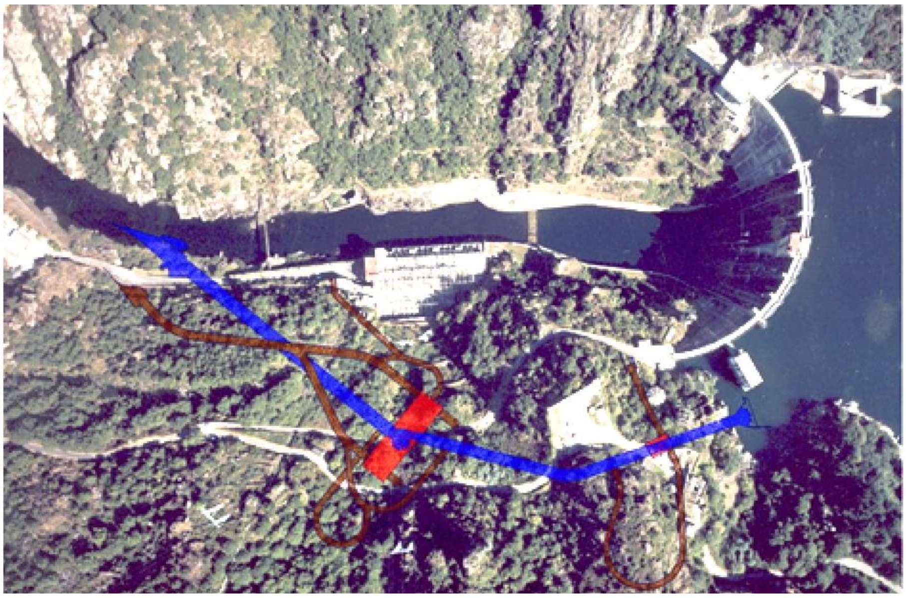

Figure 1. Photo-sketch of the San Esteban Scheme.

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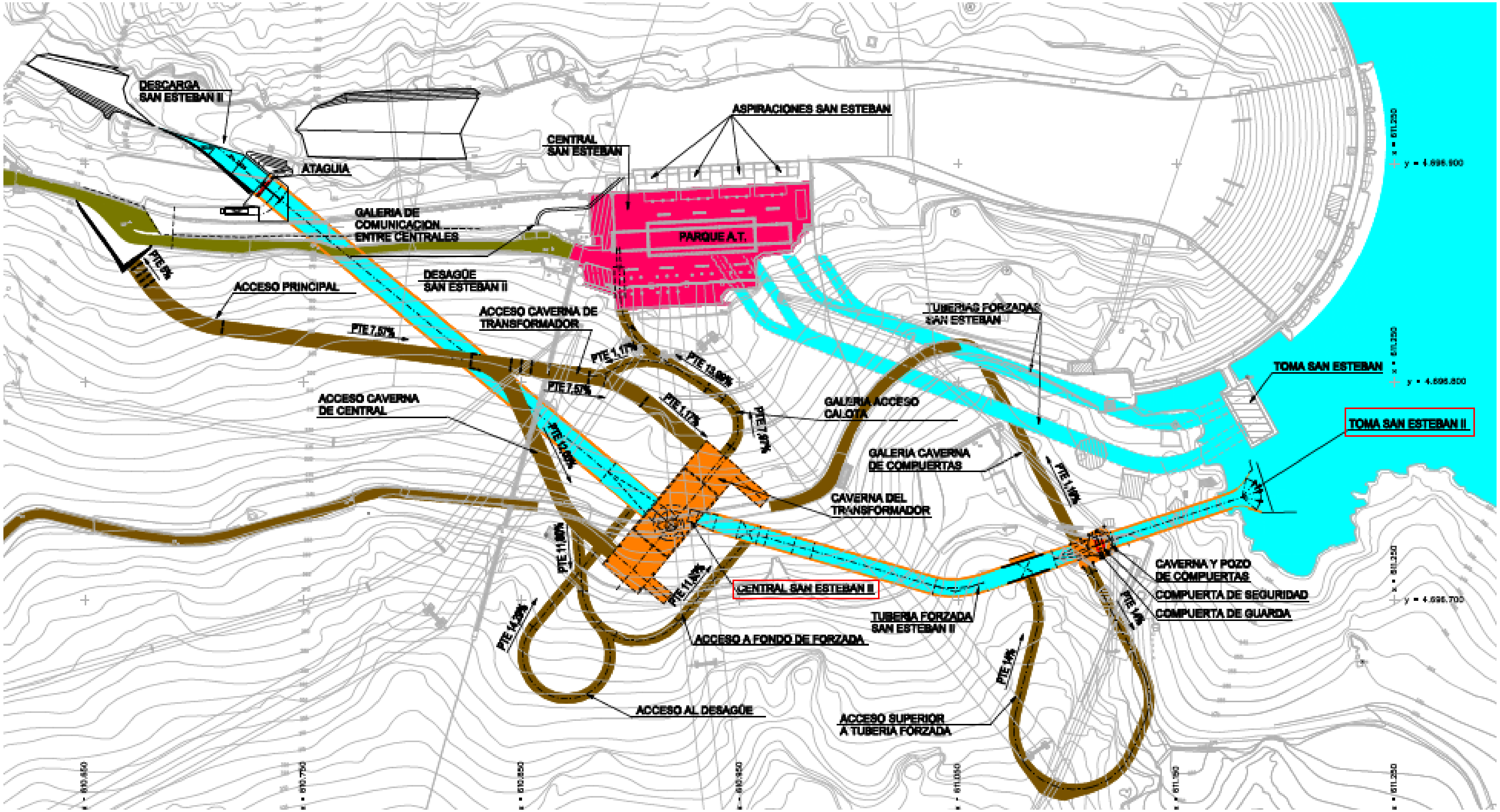
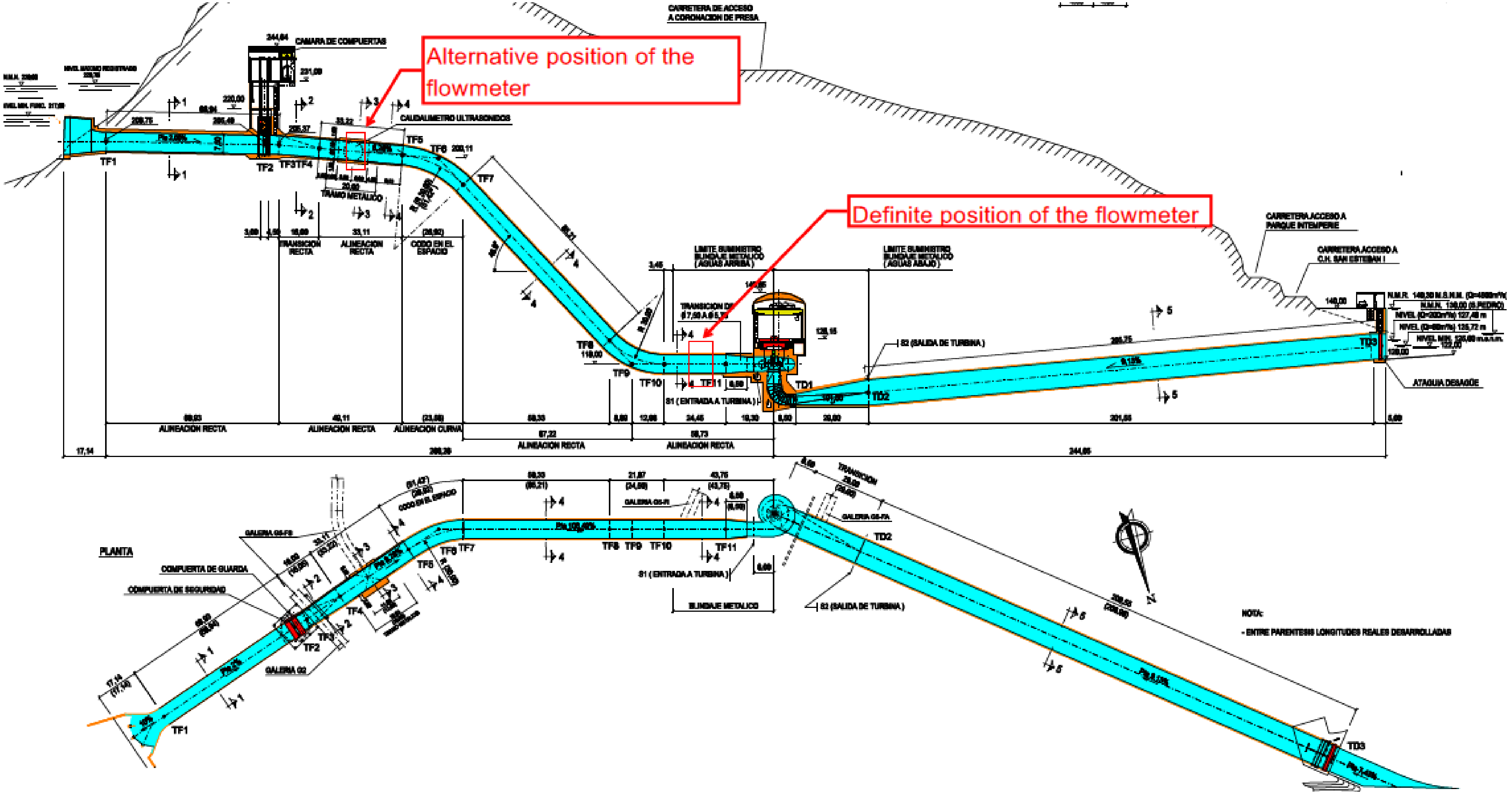


Figure 1 Lay-out of the San Esteban II and dam and the older HPP San Esteban. Power stations, roads, galleries and hydraulic loop can be seen


Alternative position of the flowmeter

Definite position of the flowmeter

Figure 3.- San Esteban II hydraulic configuration

2.- Guarantees and specified uncertainties and penalties

An appreciable investment has been made for the San Esteban II completion (130 M€). The recovery of it is very dependent of the main machine behaviour:

- Robustness of the components,
- Reliability,
- Adequate and adapted response to the transient episodes (small overpressures, over speeds, runaway...) and
- Power and efficiency to be reach.

It’s evident the first goal for a hydraulic power station must be an operation free of faults and damages and a long life of all components. If this premise would be fulfilled, the most powerful and efficient machine must to be selected.

For San Esteban II machine purchase process were invited a number of well recognised Manufacturers. All of these offered very similar characteristics in the 3 first subjects mentioned above. However significant scatter appears in the 4th one.

The scatter in the figures to be guaranteed, the amount in uncertainty of it figures, etc., means for the Plant Owner, to increase the financial risks. As remedial for it was established, first, a penalty of 250.000 € per each 0,1% of “less than guaranteed efficiency”. After a number of meetings and conversations the scatter was dramatically reduced. Anyway, this situation will be absolutely avoided since the penalties don’t cover the overall negative impact for the Owner.

The second aspect to be taken into account is the fact that uncertainty (in the hydraulic sense) means, truly, an amount of risks (in financial sense).

Face to the aim to reduce the measurement uncertainty the Standard IEC 60.041 offer a figures absolutely conservative, larger than technology offers, comfortable for the manufactures but nothing at all for the Clients. An excessive tolerance in the uncertainty band means that in fact the penalties don’t have any dissuasion effect against Manufacturers with no margin.

In this way IIC (Iberdrola Ingeniería y Construcción) has had, in the very earlier times of the project, a number of conversations with reputed independent specialists in efficiency tests. As results a number of issues in the discharge method, in the straight length to be respected and in the figures of uncertainty have been obtained. All these issues have been incorporated to the Purchase Technical Specification of the turbine, and accepted by the manufacturer awarded. The uncertainty values to be mandatory in the Contract are described in the next chapter.

3.- Selection of the discharge method for the acceptance tests

During the first meetings the lights have been focussed in the following methods: current-meters, thermodynamic and ultrasonic. Other method such as the Gibson or salt injection have been ignored because the IIC-lack of experience in, the spread in results, the time between tests and the output of the results or the cost and time intervention disturbing the normal operation of the machine or by a combination of them.

Current-meters method is well known by IBERDROLA Staff since it has been the predominant one in the period 1970 to 2000. Is these decades more than 90 machines have tested by this method: in penstocks until 9 m diameter and open channels 10 m width or more. However, apart from the cost and immobilisation time of the machines the fact that every time a number of current-meter becomes out of order, reducing the quality of measurements, and the fact that the uncertainty of the method has not been evolved in a sense of a reduction (at least we haven't any new about it) has dissuaded us to select it.

Thermodynamic is another classical one, also well known by our Company, but it is true, with less realisations. IBERDROLA prefers the method for the case of higher heads and lower size penstocks. For San Esteban the head were in very limit of the recommendations for this method; furthermore, the very big area of the inlet and outlet sections means an important number of temperature problems, a very large structure to support them and a complication by the fact than cooling water and it returns were inside the downstream measuring section. A not plenty satisfactory figure in uncertainty by these facts was also a decisive argument to refuse it.

The final decision has been taken selecting the ultrasonic method. However a number of strategic questions have had to be afforded and solved prior to develop it. The first action to implement the ultrasonic as discharge measurement method has been to check it feasibility in the follow aspects:

- To select a measuring section
- To select the number of paths and it disposal
- To define a realistic uncertainty acceptable by all parts (the turbine manufacturer and the plant owner).
- To compare this uncertainty with the precluded one by the IEC 60.041.
- To check the cost of the flowmeter, it installation and Commissioning and the estimation of the out of operation of the plant during these activities and the acceptance tests it selves.
- To evaluate every aspects and to connect them.

To take the right decision IIC has been accompanied by a number of experts who have confirmed the mean lines of the measurement strategy. The main conclusions were:

1. It was possible to have good quality discharge measurements in the case of San Esteban II, despite the restrictions of the IEC 60041 and the lack of straight lengths up and downstream the flowmeter. Please, remember that the standard requires a straight length of 10*D upstream and 3+D downstream the measuring section.
2. Since the main source of uncertainty in this case, is connected to the integration of flow velocity fields, the number of paths was a critical decision. Indeed the ASME PTC18 code (quite more modern) states acceptable accuracies can be achieved when and 8-path meter is located five diameters downstream of 54-degree elbows with (r/d) greater than 3. Clearly, the close proximity of the meter section with respect to the first elbow and the fact that a dual plane elbow is further upstream requires 18 acoustic paths flow rate measurement.
3. To select a world class flowmeter manufacturer, including not only the apparatus itself but the previous process of marking of probe positions, assembling, cabling and commissioning of the flowmeter. Particularly important were all the checks and demonstration of the traceability of all quantities from the readings (time of fly, delta times, signal delays, etc.) to the results as the IEC 60041 Standard requires for this method.

5. The cost of the flowmeter was not negligible in absolute terms, however was in the order of the loss of revenues due to a fall of 0,1% in efficiency in the whole life of the machine.
6. The figure of uncertainty established in the Technical Specification was ±0,50% for the discharge. It was define this value as a limit and the supplier would be aligned to it. The Supplier was responsible for a high quality implementation of the probes, key question for the success of the measurements.
7. Any case, the final uncertainty would be defined after the tests regarding all circumstances during the tests (mainly due to the random uncertainties). The reality has been better.

Then stated the strategic aspects, the details of the implementation are now afforded.

4.- Flowmeter implementation

Two measuring sections were, preliminarily, selected. See figure no.3. Both sections were the advantage to profit the presences of the end-part of an auxiliary tunnel necessary during the civil works.

The first one was the placed upstream the gates in the upper side of the penstock. This section was preferable, regarding the measurements accuracy. However it required the installation of a metallic portion of penstock with an additional cost. In the other had the gain in accuracy against the second place were quasi-testimonial. The alternative, selected definitely, has been to choice a section near the machine, downstream an elbow in the lower part of the penstock. In this side the penstock was yet metallic and no over-costs were needed. See also, figures no.3 and 4. The hydraulic aspects of the selected section are discussed in the chapter 5.

Originally an accessible external part of the penstock was planned. The aim of this concept was to have an easy access to the transducers for the exact adjusting of them during the commissioning and the further maintenance purposes.

However during the phase of engineering design revision both, the turbine (and penstock also) manufacturer and the IIC Civil engineers were reflected upon the lack of recovery in the interphase concrete-steel of the penstock in both sides. In the upstream one the presence of the elbow and in the downstream one the convergent until the spiral case inlet complicate a safe design. As an important issue the full concreting of the outer of the metallic penstock was adopted.

This decision was again, a new, but minor, obstacle. The solution, see figure no.5, was to adopt a well or cup welded to the outer of the penstock to cover each transducer. Every cup has been connected to the next by means of metallic conduits. Four mean conduits convey four sets of 9 cables each in provenance of the transducers. The cables have appropriately grouped of each one quarter of the penstock in order to avoid any confusion with the signals during commissioning and operation. The conduits end in the draft tube gallery. By means of trays cables turn to the sewage and emptying pit. Then go up to the control room in a simple straight route. In the gallery the conduits end in flanges with 9 holes each where cables are passing through. In this way it is avoided an eventual fault of the transducers flanges in the penstock. Every transducer is assembled in a blind flange who is connected to it respective flange in the penstock. The flanges have a double o ring seal and are screwed in the interior of the penstock.

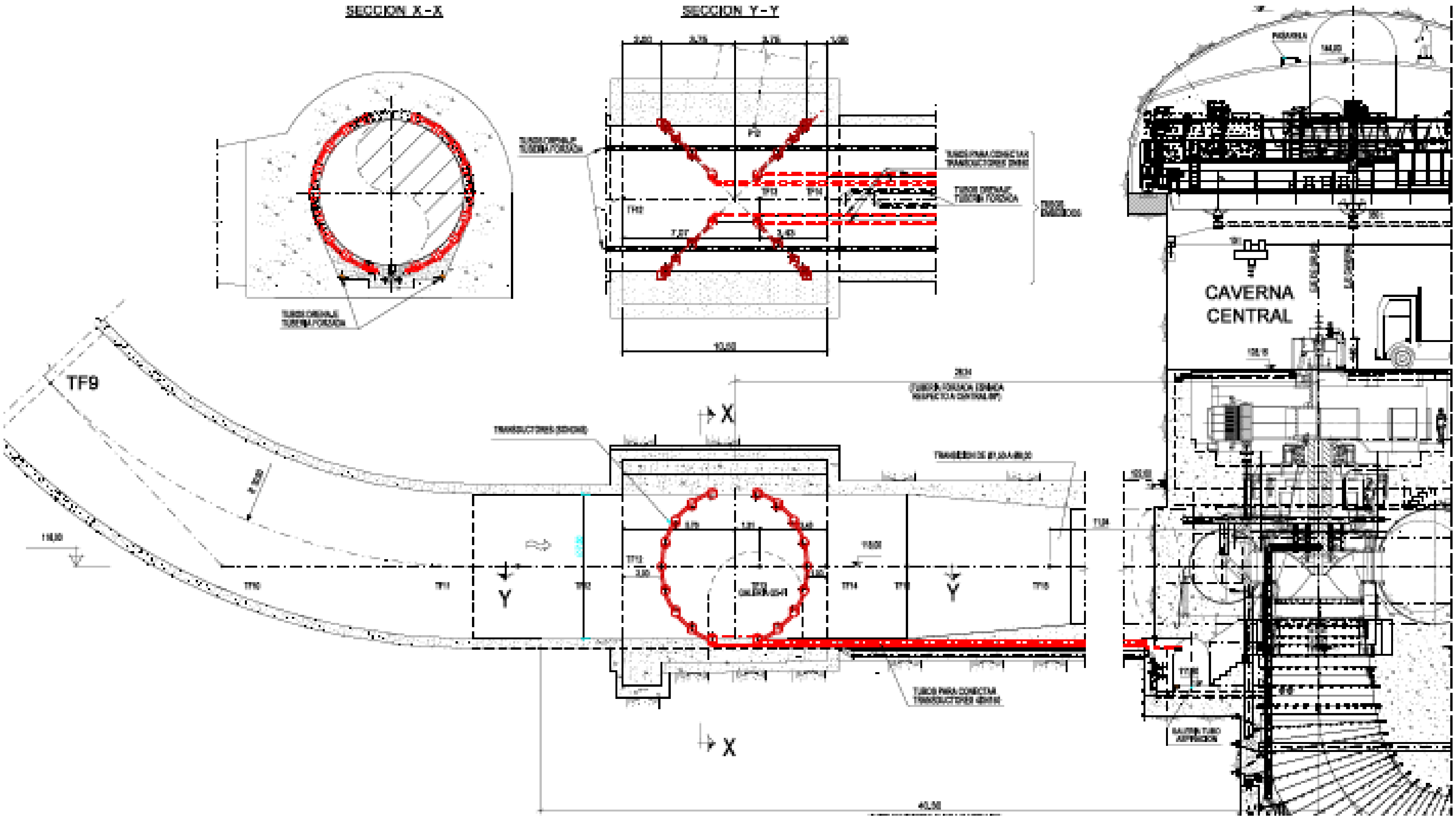


Figure 4.- Discharge measuring section of the San Esteban II. In red the cups and conduits.

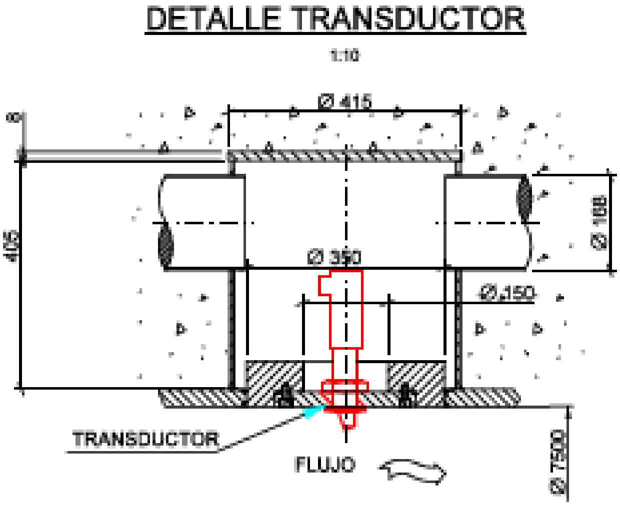


Figure 5.- Detail of the cups to cover the transducers

The tasks for erection, cabling and interconnecting transducers and electronic frames have been achieved in September 2012, prior to wet the penstock. The commissioning has been run the end of January 2013.

The first step of the erection has been the marking the transducers position. For this job a total station theodolite has been used. The distances between marks have been checked by a laser distance meter. After doing the holes and screwing the transducers in the flanges the assemblies were definitely installed. The last operation has been to get the as built readings of the transducers distances and angles.

5.- Description of the Flowmeter. Hydro-dynamic considerations.

The acoustic 18 path flow meter is installed in a 7,5 meter diameter penstock as shown in figure no. 3. Due to the limitations described above, the only available location was just one diameter upstream of a symmetrically tapered section and 1 ¼ penstock diameters upstream of 57 degree elbow with an r/d of 4. See figures no. 3 and 4.

More importantly the penstock has a complex elbow that bends in both the horizontal and vertical directions further upstream. The upstream bend in elevation is 56 degrees, and in the horizontal section, the bend is 44 degrees. Both bends have the same r/d of 4 suggesting a very low pressure loss. However, these bends distort the velocity field. Out of plane bends typically introduce swirl that does not dissipate due to angular momentum (Schlichting, 1968). Experience in lab studies indicates swirl becomes axis-symmetric 5 diameters downstream of out of plane bends. If the flow meter were installed 5 – 10 diameters downstream of this bend in the straight section of penstock uncertainty would not suffer. However, at San Esteban II, the presence of the elbow immediately upstream of the meter section, which is downstream of the dual plane bend disturbs the velocity field and symmetry is lost.

Gaussian 4 point integration (4 chords – 8 acoustic paths) is excellent at integrating functions that can be represented by polynomials of 2N-1 or 7 orders of magnitude (A.H. Stroud, 1966). When the flow is not axis-symmetric as in the case of San Esteban II higher order terms are required to approximate the velocity field and the 4 point method is not sufficient. Higher numbers of acoustic paths are required to adequately sample and integrate the distorted velocity field. The eighteen path (9 chords) flow meter was chosen since it was anticipated that the velocity field would not be symmetric and distorted. Additionally, the path placement functions are sinusoidal meaning that the 4 chords (acoustic path elevations) are a subset of the 9 chord allowing for flow calculation based on 8 acoustic paths and the 18 acoustic paths. Conclusions can be drawn on the difference between both methods of integration.

6.- Flowmeter commissioning

The flowmeter commissioning has been performed the end of January 2013 just prior to the test. Two sets of electronics were connected to each plane of transducers and were read separately by a data acquisition system. For all turbine measurements, the turbine discharge, and all velocities were logged at a 2-second interval. Each cable was traced to insure that the transducers were connected properly which was done before the penstock was watered up. Additionally the as-built measurements were checked for reasonableness assuming the penstock is a perfect cylinder. Erroneous parameter entered into the flow meter can be verified using this technique.

After the penstock was filled with water each acoustic signal was observed for proper shape and rise time characteristics (see figure 6). Furthermore it is necessary to verify that the signal to noise ratio is sufficient to properly detect the arrival time of the signal at the leading edge. Typically the leading edge of the pulse is detected at the first zero crossing as indicated by figure 6.

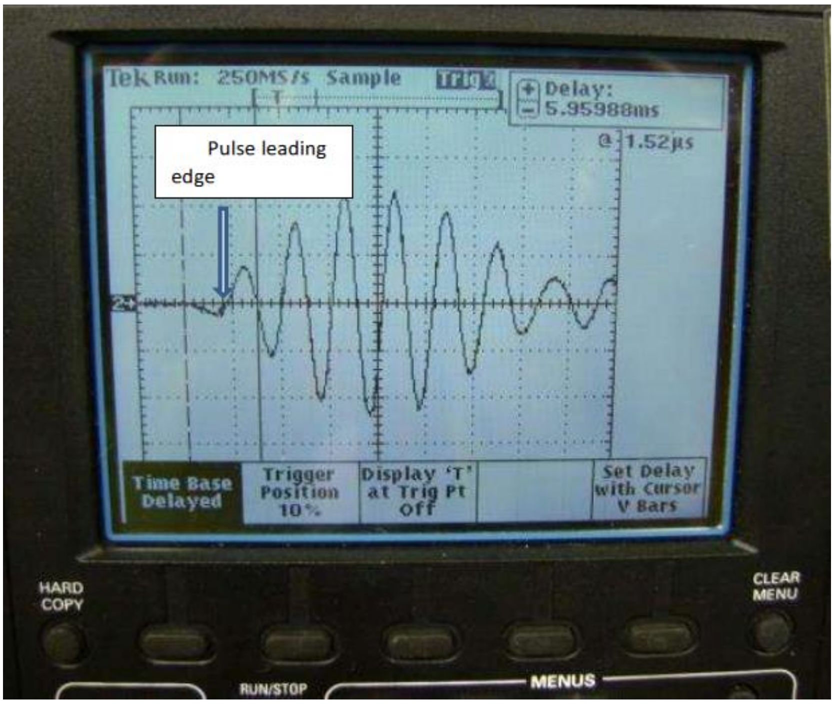


Figure 6.- Typical acoustic pulse waveform

Most flow meter systems have software algorithms to insure the leading edge is detected. If a detection point occurs at a second zero crossing an unusually high velocity is detected since the differential transit time between forward and reverse times have additional time relating to the period of the transducer or 1/ frequency. At 1 MHz, this corresponds to 1 micro second which is typically double what is measured at velocities of 4 or 5 meters per second. Acoustic flow meters measure time using timing circuits that start and stop with transmission and reception of the pulse at the electronics. There are non-water delays that are from the cable, transducer and the actual processing circuits. If these delays are properly accounted for, then the speed of sound can be determined using the forward and reverse transit times. The speed of sound in fresh water is very well know and tables of speed of sound as a function of temperature exist which permit a validation of the timing circuits and non-water delays. These checks were performed at site and any issues were resolved prior to running the testing.

7.- Acceptance tests of the machine

The efficiency tests have been performed the 1st and 4th February 2013. Previously a number of checking of the flowmeter, verification of coherence between data and measurements (ultrasonic), calibrations of pressure transducers, checking of the transducers by means of datum topographic and hydrostatic reading heads, etc., have been performed.

On the first day of testing, 27 points covering discharges from the maximum to as low as 30,9 m^3/s were made at an average head of 90,846 m (90,510 m for the region of efficiency higher than 90%). On the second day of testing 28 points have been tested the second day at an average head of 96,190 m (96,062 m for the higher efficiencies).

The stabilisation of the different points has been easy and fast. Additionally during the readings of each point tested a survey of the variation / fluctuation of head, discharge and power lead to an effective control of quality of the tests. See for instance figure 7.

In figure 7, the two load points at peak efficiency (upper) and part load (lower) can be readily observed for steady state conditions. The important parameters displayed as a function of time are readings of discharge (blue), specific energy (green) and output (red).

The test interval was chosen for 11 minutes. This time was selected based on the random variation of the flowmeter readings that typically has the largest variation of all the measured quantities. The flowmeter runs at 2 second repetition rate. A check previous to test has established a standard error for the mean of 0,128% when the number of readings was 120 and 0,109% at 154 readings.

For the reasons discussed previously, the velocity distribution as represented by the average of the two planes at each elevation (green series), is highly distorted with several inflection points indicating that functions with higher than 7 orders of magnitude (4 point integration) are required to accurately integrate the velocity distribution as shown in figure 8. The figure below is representative of the velocity profile for both heads and all ranges of flows.

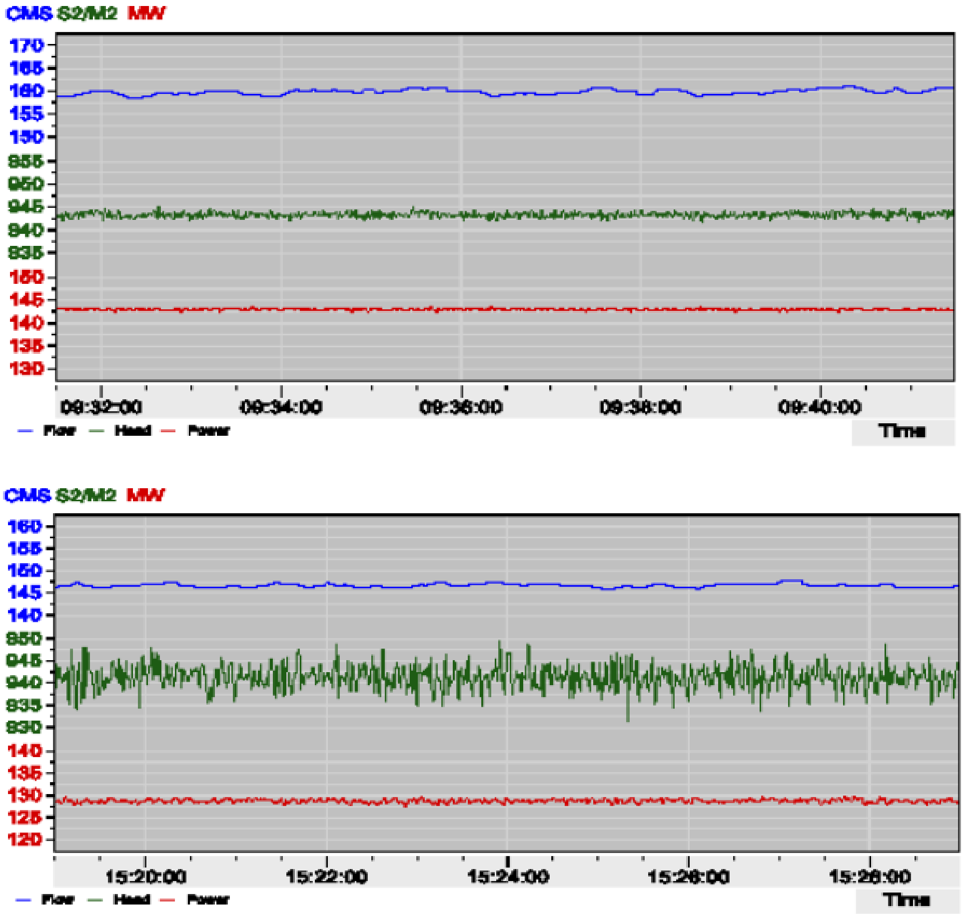


Figure 7.- Graphic to checking quantities, the second day. Point no. 2, (near the peak) and point 19, part load.

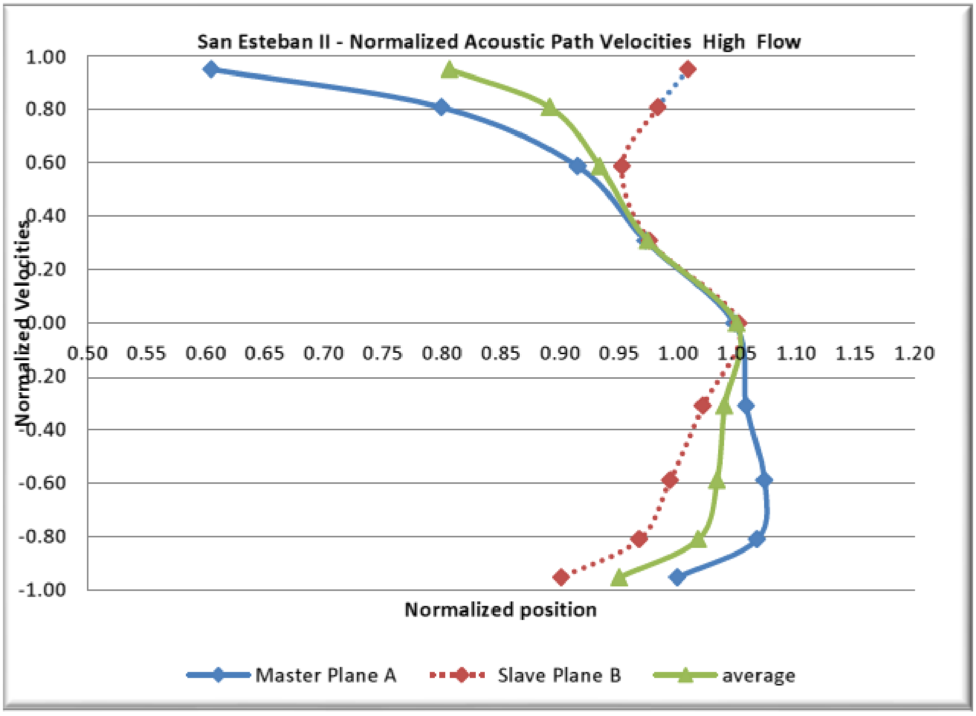


Figure 8.- Normalized Velocity distribution at high flows

The flows as calculated by both planes were reviewed for any time varying components and none were found. Below in Figure 9 the velocity distribution is presented at low flows and is very similar to the high flow rates.

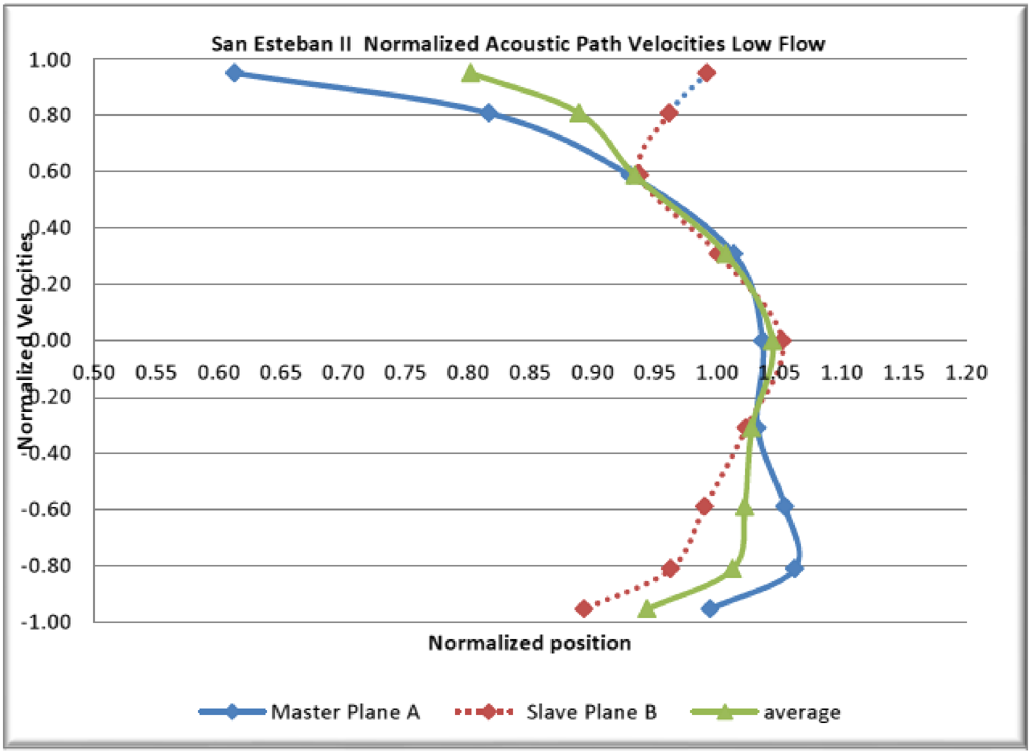


Figure 9.- Normalized velocity distribution at low flows

The results are presented in the figures 10 to 12. The values of efficiency have been converted as non-dimensions on dividing each value by the one of efficiency peak.

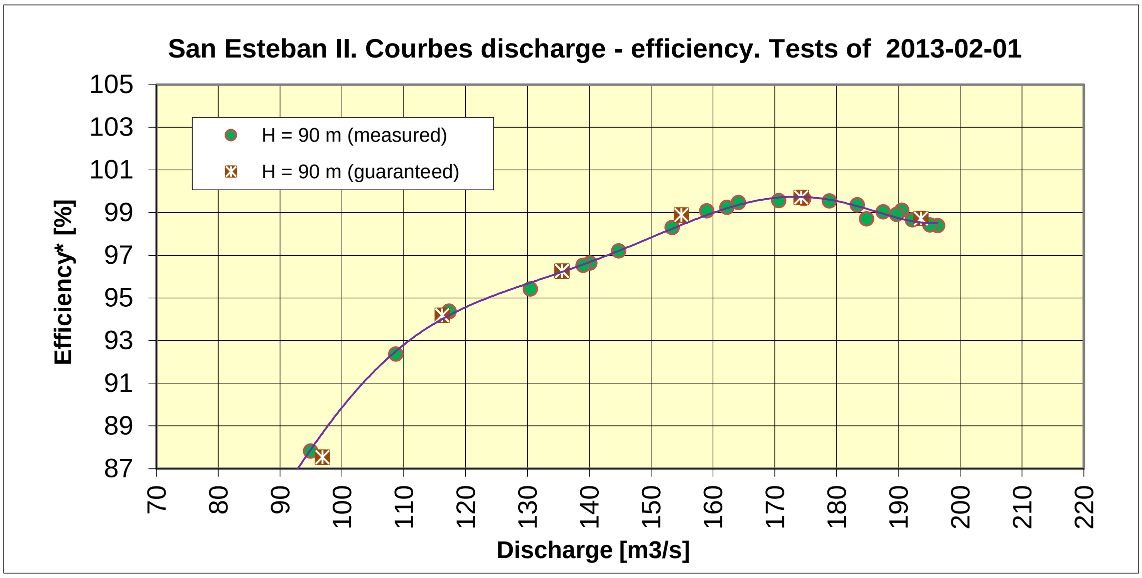


Figure 10.- Efficiency vs. discharge. Low head.

The data from tested heads have been converted to the specified ones (90, 95 and 97,5 m) using the similarity laws. Following the procedure described in the IEC 60041 the efficiencies have not been corrected since the test heads were very close to the specified ones.

From the first day the data have been used to compute results at 90 m. The data of the second day have been used to compute both 95 and 97,5 m (the second one just for comparison).

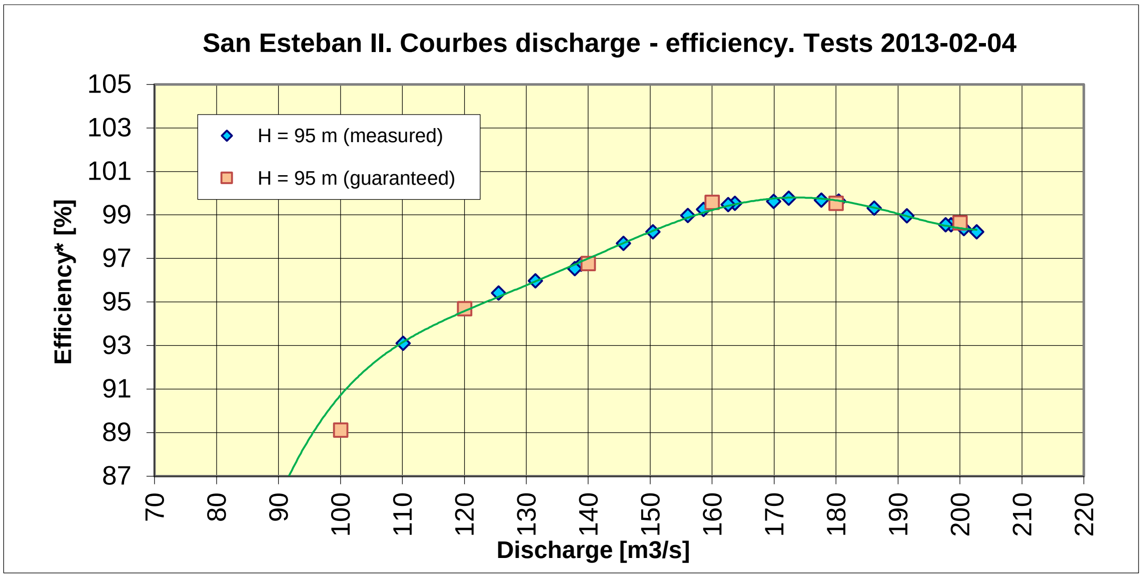


Figure 11.- Efficiency vs. discharge at high head

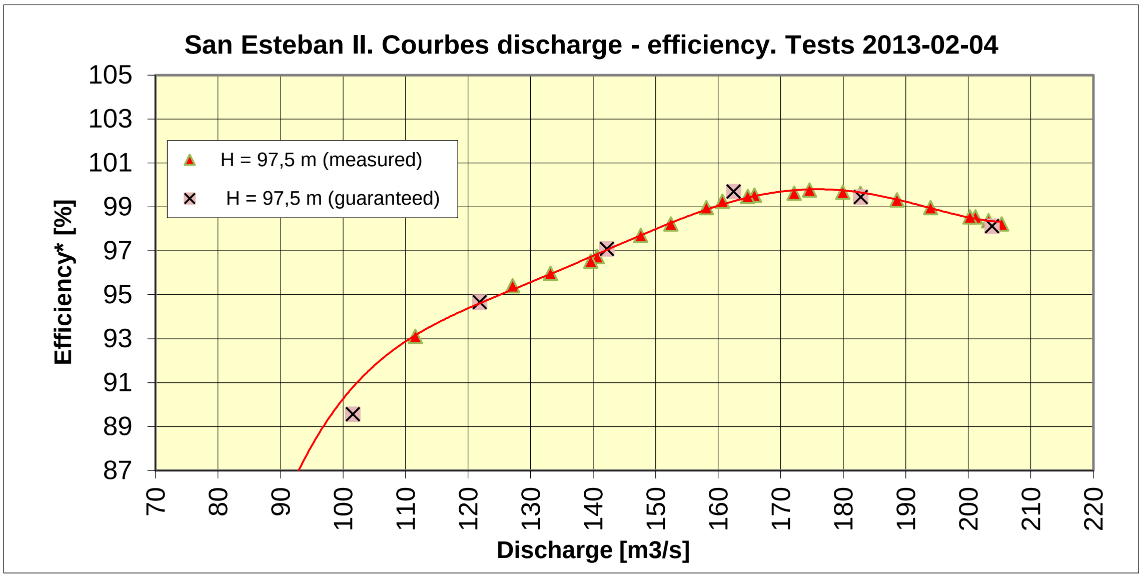


Figure 12.- Efficiency vs. discharge using extrapolation

To compare the guarantees with the results the weighted efficiency was defined in two steps: per each head is calculated a weighted efficiency as per discharge 100 and 70%.

$$\eta_{W\ head} = 0{,}46 * \eta_{70\%} + 0{,}54 * \eta_{100\%}$$

In the second step a new weighted efficiency for heads of 90, 95 and 97,5 m are computed.

$$\eta_W = 0{,}09 * \eta_{90} + 0{,}82 * \eta_{95} + 0{,}09 * \eta_{97{,}5}$$

In case of two test head (as it has been at San Esteban II) the formula becomes:

$$\eta_W = 0{,}13 * \eta_{90} + 0{,}87 * \eta_{95}$$

The resulting difference in the group weighted efficiency measured compared to the guaranteed one has been only 0,087% in less. Then, taken into account the uncertainty band means the group fulfil largely the guarantees signed between the Owner and the Manufacturer.

This coincidence between results and guarantees can be extended to the model results stepped up to the prototype conditions.

8.- Comparison results between 8 and 18 paths.

It is always interesting to check the differences between the performances of a 8 path flowmeter with a 18 path flowmeter taken into it is very fast the most of times. This is easily calculated since the Gauss-Jacoby functions that specify spacing and weights are sinusoidal and repeat. Presented in figure 13 is the range of differences between flow rates as a function of flow rate when the velocities at normalized elevations of +/- 0.309 and +/- 0.809 are calculated using the standard 8 path weighting coefficients.

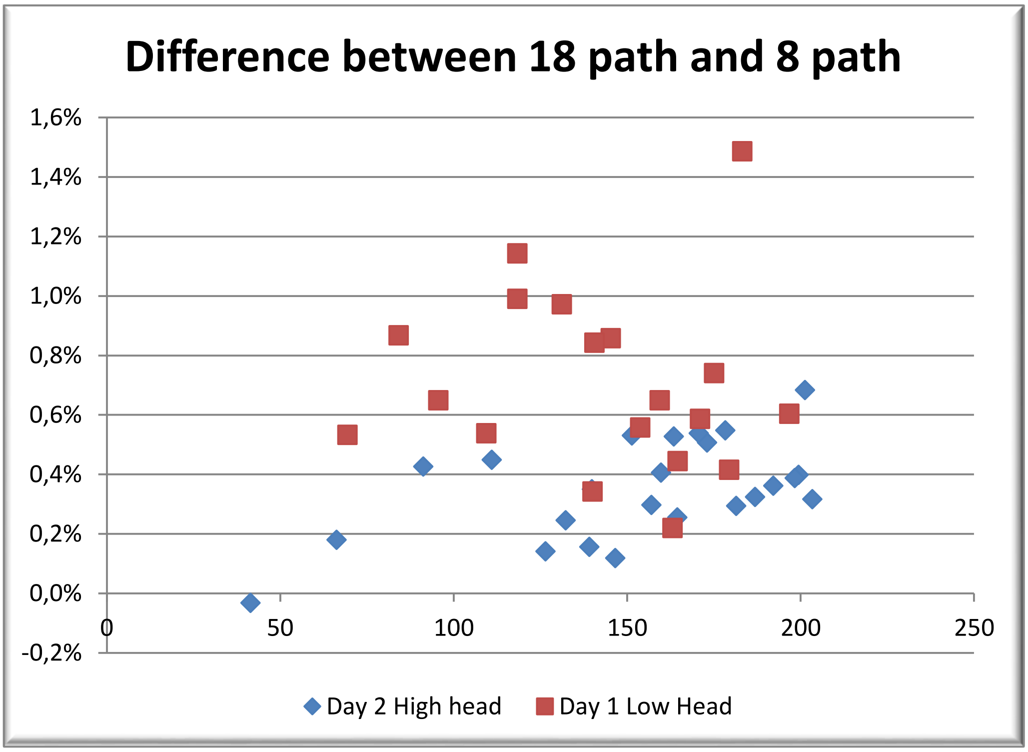


Figure 13.- Normalized velocity distribution at low flows

On average, the flows as calculated using 8 paths differ from the 18 path flow rate by 0.6%. There are larger discrepancies that are shown. Taking a run where the difference is 0.6% a 7th order polynomial curve was fit to the velocity distribution, then integrated and compared with the 18 path and 8 path flow rate. Table 1 presents the data calculated using 18 paths, 8 paths and a polynomial curve fit of 7th order.

Table 1 High Flow run

Path	Numerical Weights	W*V	18 path	8 path	residuals	W* residuals	Polynomial
1	0.0191	4.261561	0.081396		0.003487	6.66E-05	
2	0.0691	4.571292	0.315876	0.631741	0.012619	0.000872	
3	0.1309	4.645956	0.608156		0.023905	0.003129	
4	0.1809	4.675605	0.845817	1.691651	0.033037	0.005976	
5	0.2	4.704279	0.940856		0.036527	0.007305	
6	0.1809	4.335349	0.784265	1.568546	0.033037	0.005976	
7	0.1309	4.20518	0.550458		0.023905	0.003129	
8	0.0691	4.006277	0.276834	0.553657	0.012619	0.000872	
9	0.0191	3.628925	0.069312		0.003487	6.66E-05	
Discharge			197.2781	196.0707		1.208185	200.8909
				0.61%		**0.61%**	**1.80%**

Table 1 presents the data for a high flow run on the where the difference between 8 path flow and 18 path flow is calculated by each technique and using a polynomial curve fit and integrating the area under the polynomial. The residuals are calculated at each point and the resultant discharge is accounts for all of the discrepancy.

Table 2 Second run with higher difference

Path	Numerical Weights	W*V	18 path	8 path	Residuals	W* residuals	Polynomial
1	0.0191	3.939016	0.075235		0.003856	7.37E-05	
2	0.0691	4.205295	0.290586	0.581161	0.013954	0.000964	
3	0.1309	4.303011	0.563264		0.026435	0.00346	
4	0.1809	4.333560	0.783941	1.567898	0.036534	0.006609	
5	0.2	4.328903	0.865781		0.040394	0.008079	
6	0.1809	3.96	0.716364	1.432743	0.036534	0.006609	
7	0.1309	3.88	0.507892		0.026435	0.00346	
8	0.0691	3.69	0.254979	0.509948	0.013954	0.000964	
9	0.0191	3.35	0.063985		0.003856	7.37E-05	
Discharge			181.7999	184.4646		1.336079	185.3869
				-1.47%		**0.73%**	**1.93%**

The format of Table 2 is the same as Table 1. The difference between the planes is greater and a polynomial curve fit yields a difference in flow of nearly 2%. The difference in discharge as calculated using 8 and 18 acoustic paths is ~ 1.5%. This indicates the highly disturbed flow profile cannot be integrated using a polynomial of form (2n-1 or 7) indicating a limitation in the 4 point Gaussian method (4 chords or 8 paths). More importantly, the upper bound in the 4 point Gauss method is for this example 1.5%.

9.- Analysis of uncertainty.

The main sources of uncertainty are: in measurement of power, head and discharge. Power had a total uncertainty of ±0,194% since the measurements transformers was of class 0,2 and the power-meter had a contribution very small. The uncertainty in head was found of ±0,511%, due mainly by a shift in the calibration fitting of transducers prior and after the tests. For the discharge a detailed analysis is included in the table no.3. The systematic uncertainty taking into account a number of partial sources has been found to be ±0,396%. The contribution of the random component is quite small. The total uncertainty in discharge results in ±0,398%. The total uncertainty of the efficiency has been of ±0,676%.

Table 3 Systematic uncertainty in discharge. Sources detail

Source / general	Details / comments	partial	total
Geometric installation errors	measurement of path lengths *L* and *L*w;	0.0042%	
	measurement of acoustic path angles φ	0.0111%	
	measurement of path heights *d* and conformity with the positions prescribed		
	measurement of *D*		0,188%
Time measurements errors	time measurement / time resolution	0.0123%	
	non water path time estimation	0.0091%	
	Internal computational precision	0,0010%	
Protrusion error	uncertainty due to flow distortion around the transducers	0.0447%	
Integration error due to the hydraulic condition	existence of traverse flow components time measurement / time resolution	0.1000%	
	flow profile distortions (estimated from above)		
	integration uncertainty		0,250%
	spatial variations of speed of sound	0,1000%	
	Variation of flow velocity, speed of sound and discharge with time		0,128%
Errors due to ambient influence	general		0,100%
	error due to change in dimensions when the conduit is pressurized or experiences a temperature change		0,100%
Total systematic uncertainty			0,396%

As general comment the review of the discharge data on the selected test points indicates that 18 paths is sufficient to accurately indicate discharge and calculate efficiency. The close agreement with the guarantee and model stepped up data (not included in this paper) suggest that a very highly accurate field test can be performed using 18 acoustic paths when highly disturbed flow fields are measured.

In other when using 8 paths (4 chords or 4 point integration) the accuracy is not sufficient to accurately measure discharge has integration uncertainties of 1% or higher. This is demonstrated by the modelling of selected test runs where the difference between the 8 path and 18 path methods are observed. It has been shown, that a curve fit of a 7th order polynomial is theoretically is the upper limit of a function that can be integrated by the Gaussian 4 point method. More importantly, it is shown that integration uncertainties of 0.6 to 1.5 % are observed indicating more samples (chords) are required. This is supported by the test results that are highly correlated with the model test and would not correlate as well if an 8 path measurement were used.

10.- Conclusions.

1. The tests have been conducted with no special problems under two head near the rated conditions.
2. At least some attention should be paid to the measurements other than the most difficult such us the discharge. Consider for instance, the head.
3. The selection of the flow measurements has been a good choice. It can be included hear, the partners, the supplier, the experts conducting the Commissioning,...
4. However a precise and systematic Commissioning is needed to get the maximum performances in the flowmeter, taken into account a number of influence quantities. The first of them it is the accurate definition and measurement of the geometry of the penstock and the marking the positions of the transducers.
5. A remarkable issue is the excellent low uncertainty in discharge measurement. Indeed the final value of± 0,398% is lower than the specified in the purchase process.
6. When a highly perturbed velocity profile is integrated using the Gauss 4 point method uncertainties of up to 1.5% can be observed. Lower uncertainties requires 9 point or 18 path integration for high accuracy.
7. The efficiency figures obtained during the tests, the closeness of these to the guarantee ones and to the stepped up results from the model tests shall not be considered as a hazard but that the logical conclusion of the discharge meter selected and implemented. Indeed it shall be taken into consideration the fact that the actual straight lengths between the measuring section and the main singularity upstream has been quite short.
8. Furthermore it should be clearly stated the fact that the current standard IEC 60.041 becomes more and more obsolete face to the new (or no so new) tendencies in the acceptance tests. The ASME PTC18 constant revisions have to be taken as a mirror of the way we must take.
9. It is clear the straight lengths to be adopted in new acceptance tests shall be dramatically shorted. If the standard IEC don't cover the common, today, situations where the distances are shorts one can be forget this Standard and do by other ways. Can help to revise the Standard the fact that the number of realisations of tests without respect the minimum distances prescribed is more and more increasing.

10. A reduction in the uncertainty figures contributes to the confidence to the guarantees extended in the tenders and reduce the “uncertainties” (not only in the measurement sense) for the purchase process decision.
11. Costs of the tests shall not be forgotten. Can be in not all cases is justified a so sophisticated implementation but it merits to try it taken into account the fact that the cost is well known but most of times the overall benefits can be hidden the benefits. For instance, a realisation with 8 paths could be an interesting decision in a number of situations with short straight lengths (but no so short than in san Esteban II). Or, as alternative take the decision to admit a larger uncertainty (but no so larger as it can be described hear: in the order of the ±2,00 % approximately)

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